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Publication date:
2014

Document Version
Peer reviewed version

PO. ID 179

What makes a nacelle mounted lidar a suitable tool for power performance measurement?

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Objectives

Nacelle lidars are attractive for offshore measurements since they can provide measurements of the free wind speed in front of the turbine rotor without erecting a met mast, which significantly reduces the cost of the measurements. Nacelle mounted pulsed lidars with two lines of sight (LOS) have already been demonstrated to be suitable for use in power curve measurements [1]. **To be accepted as a validated tool however, power performance measurements performed using these instruments require traceable calibrated measurements and the quantification of the wind speed measurement uncertainty.** Here we present and demonstrate a procedure answering these needs.

Method

This poster describes the derivation of the complete uncertainty budget of a power curve measured with a two beam nacelle lidar. It focuses on the main deviations from a power curve assessed with a mast mounted cup anemometer. The main differences between the two techniques are:

1) the derivation of the uncertainty in the wind speed measurement, which highlights the need for a **traceable calibration method** for the nacelle lidar;

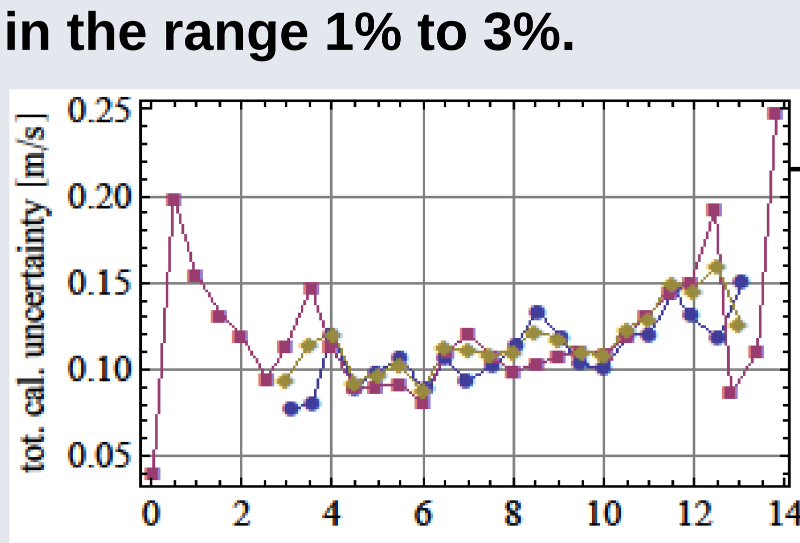
2) the varying **sensing height error** as the nacelle and lidar tilt due to the rotor thrust induced bending of the tower.

Uncertainty in lidar wind speed measurement

The lidar was installed on a 9m high platform in order to calibrate the wind speed measurement. Each of the lidar's radial wind speed measurement was compared to the wind speed measured by a calibrated sonic anemometer, projected along the LOS direction [2]. The various sources of uncertainty in the lidar wind speed measurement have been thoroughly determined:

	Uncertainties	Estimate
Uncertainty in wind speed measurement of the reference sonic anemometer	Sonic calibration (wind tunnel calibration)	0.035m/s
	Sonic operational (assuming comparable to a cup anemometer)	0.015m/s+0.15%
	Sonic mounting	0.25%
	Sonic flow distortion	0.05% per ±10°
The sonic wind speed was projected to the lidar LOS direction.	Reference wind direction measurement	0.02% per ±10°
The azimuth direction of the LOS is determined from data analysis	Lidar LOS direction	0.1%
The lidar beam must point at the same height as the height of the reference sonic anemometer.	Lidar LOS elevation	0.2%

The radial wind speed measurement uncertainty for each LOS was obtained by combining in quadrature the uncertainties identified in the table above to the radial wind speed mean deviation and standard uncertainty.
The lidar horizontal wind speed uncertainty results from the combination of the uncertainty of the two radial wind speeds. **The uncertainty in the lidar horizontal wind speed measurement was found to be in the range 1% to 3%.**

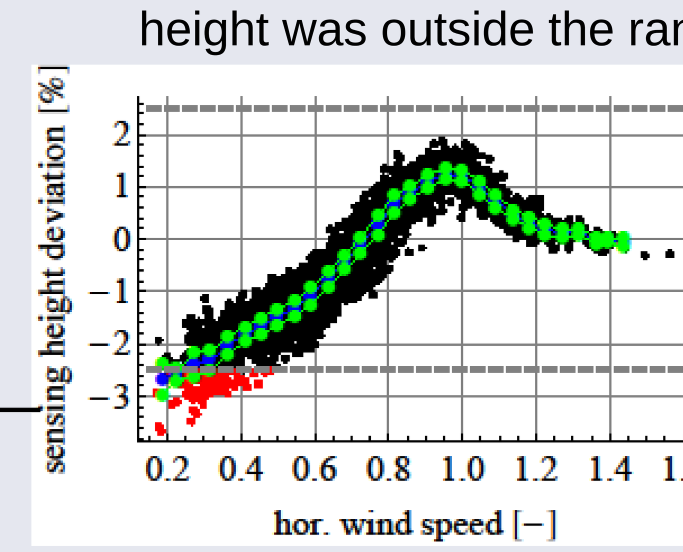


Radial wind speed measurement uncertainty for each LOS (blue and red); horizontal wind speed uncertainty (yellow)

Uncertainty in power curve

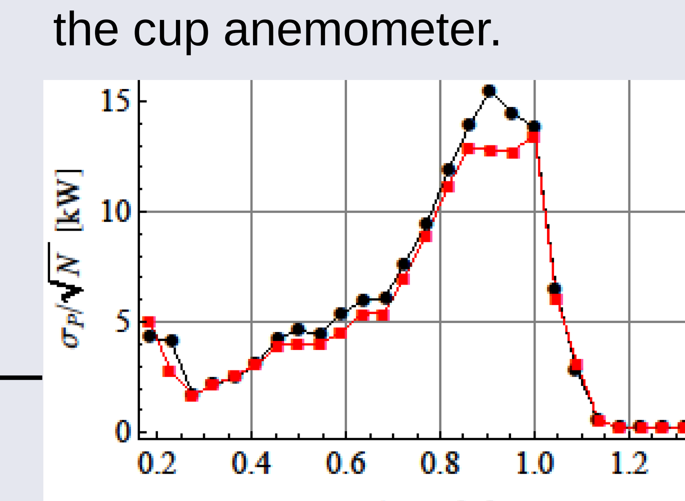
After calibration the lidar was mounted on the nacelle of a wind turbine in order to perform a power curve measurement [3]. The wind speed was simultaneously measured with a mast-top mounted cup anemometer placed two rotor diameters upwind of the turbine.

An uncertainty was added to wind speed bins for which the measurement height was outside the range.



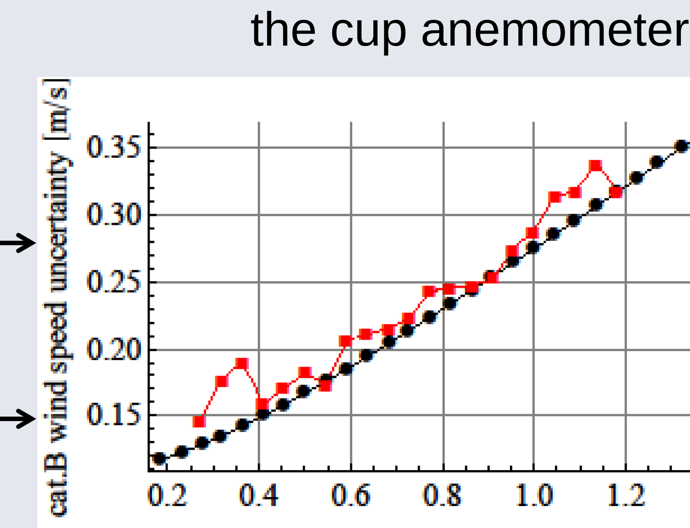
Lidar measurement height at 2.5D relative to hub height. Black and red dots: 10 min data within and without (resp) the range hub height +/- 2.5%.

The category A uncertainty is slightly smaller for the lidar than for the cup anemometer.



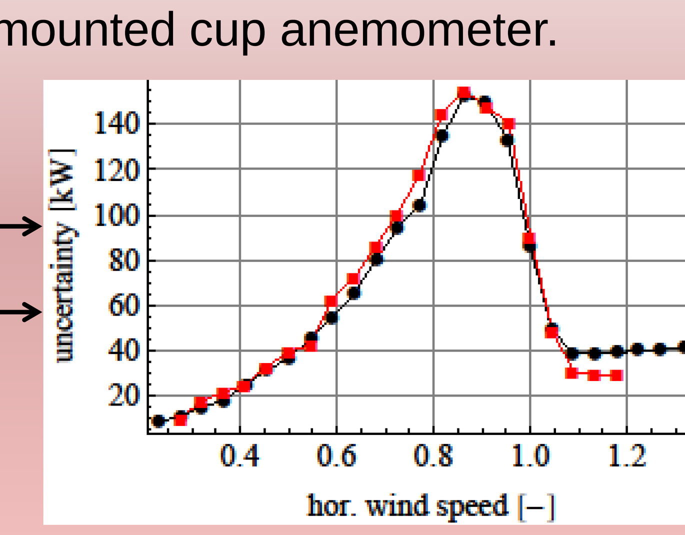
Category A uncertainty in power for the power curve measured by the mast mounted cup anemometer (black) and with the lidar (red).

The wind speed uncertainty is slightly larger for the lidar than for the cup anemometer.



Combined category B uncertainty in wind speed for the power curve measured by the mast mounted cup anemometer (black) and with the lidar (red).

The resulting combined uncertainty in the power curve using the nacelle lidar was 10kW larger on average than that obtained with the mast mounted cup anemometer.



Total uncertainty in the power curve measured by the mast mounted cup anemometer (black) and with the lidar (red).

Conclusions

A nacelle lidar can be a very good tool for power performance assessment, on the condition that the instrument is first calibrated and all the uncertainties are accounted for. Both a calibration procedure and power curve measurement procedure fulfilling these demands for a two beam nacelle lidar have been designed and tested. We have demonstrated that a nacelle lidar is a serious and highly competitive tool for performing power curve testing.

References

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Acknowledgements

This work was performed under the EUDP-2009-II project: Nacelle based LiDAR for power performance (J.nr 64009-0273). The authors would like to thank all the people who helped with the technical support , especially Anders R. Vestergaard.